Rec'd PCT/PTO 15 MAR 2005
PCT/IB 03/03913
05.09.03

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Patentanmeldung Nr. Patent application No. Demande de brevet n°

02292290.0

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

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Anmeldung Nr:
Application no.: 02292290.0
Demande no:

Anmeldetag:
Date of filing: 18.09.02
Date de dépôt:

Anmelder/Applicant(s)/Demandeur(s):

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
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Method for processing a wobble signal

In Anspruch genommene Priorität(en) / Priority(ies) claimed /Priorité(s) revendiquée(s)
Staat/Tag/Aktenzeichen/State/Date/File no./Pays/Date/Numéro de dépôt:

Internationale Patentklassifikation/International Patent Classification/
Classification internationale des brevets:

G11B7/00

Am Anmeldetag benannte Vertragstaaten/Contracting states designated at date of filing/Etats contractants désignées lors du dépôt:

AT BE BG CH CY CZ DE DK EE ES FI FR GB GR IE IT LI LU MC NL PT SE SK TR

DESCRIPTION

Field of the invention

The invention deals with an apparatus for reading and/or writing data from and /or onto a data carrier, said data carrier containing wobbled tracks, said apparatus having scanning means for scanning said tracks, detection means for detecting at least two elementary signals when scanning said tracks, and wobble recovery means for generating a wobble signal from said at least two elementary signals.

The invention also deals with an optical unit having scanning means for scanning wobbled tracks of a data carrier, detection means for detecting at least two elementary signals when scanning said tracks, and wobble recovery means for generating a wobble signal from said at least two elementary signals.

The invention also deals with a wobble processing method for processing a wobble signal generated from at least two elementary signals detected by scanning a wobbled track of a data carrier.

The invention also deals with a program comprising instructions for implementing such a wobble processing method when said program is executed by a processor.

The invention applies to any data carrier format using wobbled tracks. For instance it applies to inscribable and re-inscribable optical discs in which the tracks are wobbled, like DVD+RW, DVD+R, DVD-RW, Blu-Ray...

Background of the invention

US patent n° 5,631,892 deals with the deterioration of the wobble/noise ratio due to a deviation in the positioning of the detector. A solution is described to cancel that noise. It consists in adjusting a weighting ratio between the two signals that are detected and that contribute to the wobble signal so as to make the DC component of the wobble signal equal to zero. This solution is based on the assumption that the noise component in the wobble signal is proportional to the deviation of the detector position.

This assumption cannot be hold for some type of aberrations that also lead to radial asymmetry in the two halves of the detector, and therefore to a leakage of data in the wobble signal.

An object of the invention is to propose a solution for eliminating the noise of various origins in the wobble signal, notably the high frequency data leakage into the wobble signal due to radial asymmetry introduced in the diffraction pattern on the detector, whatever the reason for this radial asymmetry.

Summary of the invention

This is achieved with an apparatus for reading and/or writing data from and/or onto a data carrier as claimed in claim 1, with an optical unit as claimed in claim 5, with a wobble processing method as claimed in claim 8, and with a program as claimed in claim 11.

The invention uses at least one adaptive filter for filtering the elementary signals that are detected by said detection means and generates an improved wobble signal by subtracting said filtered elementary signals from said wobble signal.

The invention works adaptively and it allows to cancel any noise originating from high frequency data written on tracks over the full bandwidth regardless of the spectrum relationship between the noise signal and the wobble signal. The only assumption made in the invention is that the noise signal is a filtered version of the data signal.

In a first embodiment of the invention, data recovery means are provided for generating a data signal from said at least two elementary signals, and the adaptive filter uses filtering coefficients chosen so as to minimize the cross-correlation between said improved wobble signal and said data signal. In this embodiment the adaptation is driven by a decorrelation mechanism. With this embodiment any undesired signal can be removed from the wobble signal as far as the pure wobble signal is uncorrelated with this undesired signal.

In a second embodiment of the invention, the adaptive filter uses filtering coefficients chosen so as to minimize the difference between a scaled version of the improved wobble signal and a reference wobble signal reconstructed based on the generated wobble signal. In this second embodiment an undesired signal may be removed from the wobble signal even if correlated to the wobble signal. This embodiment is more complex and it introduces a delay because the reference wobble signal has to be reconstructed based on the results of the wobble detection before the adaptation starts.

Brief description of the drawings

These and other aspects of the invention are further described with reference to the following drawings:

- figure 1 is a schematic representation of a data carrier having wobbled tracks,
- figure 2 is an example of an apparatus according to the invention for reading and/or writing data from and/or onto a data carrier,
- figure 3 is a block diagram of a first embodiment of a wobble processing circuit according to the invention,
- figure 4 is a block diagram of a second embodiment of a wobble processing circuit according to the invention,
- figure 5 is a typical example of the frequency spectrum of a wobble signal before and after the processing according to the invention.

Description of preferred embodiments

Figure 1 shows an inscribable data carrier 1, figure 1A being a plan view, figure 1B showing a small part in a sectional view taken on a line b-b, and figure 1C showing a portion 2 of the data carrier in a larger scale. The data carrier 1 of figure 1 is a disc having tracks forming each a 360° turn of a spiral line 3. Each track comprises a groove 4 and a land 5. For the purpose of recording data, the data carrier has a recording layer 6, which is deposited on a transparent substrate 7 and which is covered by a protective coating 8. The data are recorded in the grooves 4. The tracks are scanned by a radiation beam that enters the data carrier through the substrate 7.

As represented in figure 1C, the tracks have a continuous sinusoidal deviation from their average centreline. This sinusoidal deviation is called wobble. In some implementations, the wobble is used for tracking (keeping the spot on the tracks) as an alternative to the known "one-spot push-pull" or "3-spot push-pull" methods. This is not mandatory. In some standards, the wobble is modulated to carry addressing information. For instance in DVD+RW, DVD+R and DVR (Blue-Ray) the wobble is phase modulated. In DVD-RW it is frequency modulated.

Figure 2 shows an example of apparatus for reading / writing data from / onto the data carrier 1. The apparatus of figure 2 comprises a radiation source 10, for instance a semiconductor laser. The radiation source 10 generates a beam 11 that is directed onto a track of the data carrier 1 by means of an optical system comprising, inter alia, a focussing objective 12.The beam 11 produces a small spot 13 on the data carrier 1. For the spot 13 to scan the tracks, the data carrier is rotated about a shaft 14 by a motor 15 in a conventional manner. The beam 11 is reflected by the data carrier 1. The projected and reflected beams are separated one from the other by a beam splitter 16 (for example a partially transparent mirror). The reflected radiation beam 17 is passed on to a quadruple photo detector 20 having a radiation sensitive surface divided into four quadrants Q_A, Q_B, Q_C and Q_D.

The detector 20 generates four photocurrents A, B, C and D (also called elementary signals) corresponding to the power of the radiation incident on each of the four quadrants of the radiation sensitive surface. These four elementary signals A, B, C, D are passed on to data / wobble recovery means 22. They are also passed on to a wobble processing circuit 24 in accordance with the invention. The data / wobble recovery means 22 generate a data signal D_{OUT}=A+B+C+D, and a difference signal PP=A+B-C-D.

In certain embodiments of the invention, as will be apparent in the following of the description, the data signal D_{OUT} is passed on to the wobble processing circuit 24.

The difference signal PP is passed on to a low pass filter 25 which blocks the signal components caused by the wobble (the signal components caused by the wobble are beyond the tracking bandwidth). After filtering the difference signal is fed to a servo circuit 26 responsible for controlling the position of the spot 13 in a direction perpendicular to the direction of the tracks (the servo circuit 26 controls either the position of the optical system or the position of the focussing objective 12).

The difference signal PP is also passed on to the wobble processing circuit 24. The wobble processing circuit 24 generates an improved wobble signal IPP in which the data-to-wobble crosstalk has been removed. The improved wobble signal IPP is passed on to a demodulation circuit 27 responsible for extracting the addressing information carried by the wobble signal. This addressing information is passed on to a microprocessor 28. For instance, this addressing information is used by the microprocessor 28 to derive the current position of the spot 13 on the data carrier 1. During reading, erasing or writing the microprocessor 28 can compare the current position of the spot 13 with a desired position and determine parameters for a jump of the optical system to the required position. The parameters of the jump are fed to the servo circuit 26.

The data D_{IN} to be written on the data carrier 1 are modulated by a modulation circuit 29 and fed to the microprocessor 28. The microprocessor 28 synchronizes the data D_{IN} with the addressing information generated by the demodulation circuit 27, and generates a control signal passed on to a source control unit 30. The source control unit 30 controls the optical power of the beam 11 emitted by the radiation source 10 thereby controlling the formation of marks in the grooves of the data carrier 1.

Figure 3 is a block diagram of a first embodiment of a wobble processing circuit according to the invention. The wobble processing circuit of figure 3 comprises a set 40 of four adaptive filters F_A, F_B, F_C and F_D, a coefficients calculation block 42 and a subtracting unit 44. The elementary signals A, B, C and D are fed to the adaptive filters F_A, F_B, F_C and F_D respectively. The subtracting unit outputs an improved wobble signal IPP:

$$IPP = PP - [F_A * A + F_B * B + F_C * C + F_D * D].$$

The data signal D_{OUT} and the improved wobble signal IPP are fed to the coefficients calculation block 42. The coefficients calculation block 42 is responsible for calculating the coefficients of each of the four filters F_A, F_B, F_C and F_D by minimizing a cost function J:

$$J(F_A, F_B, F_C, F_D) = \{E\{IPP \times D_{OUT}\}\}^2$$

where $E\{\ \}$ is the mathematical expectation. This cost function J gives the cross correlation between the improved wobble signal IPP and the data signal D_{OUT}.

Classically, the cost function J is minimized by using the gradient algorithm:

$$F_A(k+1) = F_A(k) + \mu_A \times \left[-\frac{\partial J(F_A, F_B, F_C, F_D))}{\partial F_A} \right]_{F_A = F_A(k)}$$

$$F_B(k+1) = F_B(k) + \mu_B \times \left[-\frac{\partial J(F_A, F_B, F_C, F_D))}{\partial F_B} \right]_{F_B = F_B(k)}$$

$$F_C(k+1) = F_C(k) + \mu_C \times \left[-\frac{\partial J(F_A, F_B, F_C, F_D))}{\partial F_C} \right]_{F_C = F_C(k)}$$

$$F_D(k+1) = F_D(k) + \mu_D \times \left[-\frac{\partial J(F_A, F_B, F_C, F_D))}{\partial F_D} \right]_{F_D = F_D(k)}$$

where:

- $\frac{\partial J(F_A, F_B, F_C, F_D)}{\partial F_A}$, $\frac{\partial J(F_A, F_B, F_C, F_D)}{\partial F_B}$, $\frac{\partial J(F_A, F_B, F_C, F_D)}{\partial F_C}$, and $\frac{\partial J(F_A, F_B, F_C, F_D)}{\partial F_D}$ are the gradient of $J(F_A, F_B, F_C, F_D)$ with respect to F_A, F_B, F_C and F_D respectively,
- μ_A, μ_B, μ_C, and μ_D are convergence factors that control the stability and the rate of adaptation,
- and k is the time index.

In practice, for executing the gradient algorithm, the instant value of $(IPP \times D_{OUT})^2$ replaces the mathematical expectation $\{E\{IPP \times D_{OUT}\}\}^2$ that is unknown a priori.

Figure 4 is a block diagram of a second embodiment of a wobble processing circuit according to the invention. The wobble processing circuit of figure 4 comprises a set 50 of four adaptive filters F_A, F_B, F_C and F_D, a coefficients calculation block 52 and a subtracting unit 54. The elementary signals A, B, C and D are fed to the adaptive filters F_A, F_B, F_C and F_D respectively. The subtracting unit outputs an improved wobble signal IPP:

$IPP = PP - [F_A * A + F_B * B + F_C * C + F_D * D]$.

The improved wobble signal IPP is fed to the coefficients calculation block 52. In this embodiment the cost function J to be minimized by the coefficients calculation block 52 is defined as follows:

$J(F_A, F_B, F_C, F_D, q) = E\left\{(q \times IPP - PP_{REF})^2\right\}$ where:

- q is a constant to be decided together with F_A, F_B, F_C and F_D by using the gradient algorithm

$$q(k+1) = q(k) + \mu_q \times \left[-\frac{\partial J(F_A, F_B, F_C, F_D, q))}{\partial q} \right]_{q=q(k)}$$

- and P_{REF} is a reference wobble signal that is reconstructed based on the results of the wobble detection (a result of the wobble detection is a value above zero or below zero for a phase modulated wobble, a positive value corresponds to a sine wave of one period while a negative value corresponds to an anti-phase sine wave of one period ; by assembling these one period sine waves end to end, an ideal sine wave is rebuilt that is used as reference signal PP_{REF}).

In practice, for executing the gradient algorithm, the instant value of $(q \times IPP - PP_{REF})^2$ replaces the mathematical expectation $\{E\{q \times IPP - PP_{REF}\}\}^2$ that is unknown a priori.

Alternative embodiments (that are not represented in the drawings) use:

- one single filter F ($IPP = PP - [F * D_{OUT}]$),
- or two filters F_{A+B} and F_{C+D} ($IPP = PP - [F_{A+B} * (A+B) + F_{C+D} * (C+D)]$),

instead of the above described sets 40 and 50 of four filters.

These alternative embodiments are used when the four elementary signals A, B, C and D are not individually available (for instance when the detector is a two quadrant detector). They can also be chosen although the four individual elementary signals are available because they induce less computations.

In figure 5 the general form of the frequency spectrum of a wobble signal PP and its corresponding improved wobble signal IPP is represented (the Y-axis indicates the power and the X-axis indicates the frequency). It can be seen from these curves that in the improved wobble signal the noise is significantly decreased over the full bandwidth.

It is to be noted that the wobble processing method of the invention can be implemented either in hardware or in software on a digital signal processor.

With respect to the described processing method, optical unit, and reading/writing apparatus, modifications or improvements may be proposed without departing from the scope of the invention. The invention is thus not limited to the examples provided.

In the embodiment described with reference to figure 2, the wobble is a modulated signal used to carry location information but not for tracking. This is not restrictive. The data-to-wobble crosstalk is due to radial asymmetry introduced in the diffraction pattern on the detector. This asymmetry is independent on the wobble itself. It appears in pure periodic wobbles as well as in frequency or phase modulated wobbles. Thus the invention is applicable independently on the type of wobble signal (pure periodic or modulated wobble signal) and independently on the way the wobble signal is used in the reading and/or writing apparatus (used for tracking and/or carrying information).

The embodiment of figures 2, 3 and 4 use a quadruple photo detector. This is not restrictive. For instance a double photo detector having a dividing line running parallel to the direction of the tracks to be scanned can be used instead of a quadruple photo detector.

The word "comprising" does not exclude the presence of other elements or steps than those listed in the claims.

CLAIMS

1. An apparatus for reading and/or writing data from and /or onto a data carrier, said data carrier containing wobbled tracks, said apparatus having scanning means for scanning said tracks, detection means for detecting at least two elementary signals when scanning said tracks, wobble recovery means for generating a wobble signal from said at least two elementary signals, and wobble processing means for filtering said at least two elementary signals with at least an adaptive filter, and for generating an improved wobble signal by subtracting said filtered elementary signals from said wobble signal.

2. An apparatus as claimed in claim 1, having data recovery means for generating a data signal from said at least two elementary signals, wherein said adaptive filter uses filtering coefficients chosen so as to minimize the cross-correlation between said improved wobble signal and said data signal.

3. An apparatus as claimed in claim 2, wherein said filtering coefficients are updated by using an iterative gradient algorithm minimizing a cost function having an instant value equal the instant value of the squared product of said improved wobble signal and said data signal.

4. An apparatus as claimed in claim 1, wherein said adaptive filter uses filtering coefficients chosen so as to minimize the difference between a scaled version of the improved wobble signal and a reference wobble signal reconstructed based on the generated wobble signal.

5. An optical unit having scanning means for scanning wobbled tracks of a data carrier, detection means for detecting at least two elementary signals when scanning said tracks, wobble recovery means for generating a wobble signal from said at least two elementary signals, and wobble processing means for filtering said at least two elementary signals with at least an adaptive filter, and for generating an improved wobble signal (IPP) by subtracting said filtered elementary signals from said wobble signal.

6. An optical unit as claimed in claim 5, having data recovery means for generating a data signal from said at least two elementary signals, wherein said adaptive filter uses filtering coefficients chosen so as to minimize the cross-correlation between said improved wobble signal and said data signal.

7. An optical unit as claimed in claim 5, wherein said adaptive filter uses filtering coefficients chosen so as to minimize the difference between the improved wobble signal and a reference wobble signal reconstructed based on the generated wobble signal.

8. A wobble processing method for processing a wobble signal generated from at least two elementary signals detected by scanning a wobbled track of a data carrier, comprising a filtering step for filtering said at least two elementary signals with at least an adaptive filter, and a subtracting step for subtracting said filtered elementary signals from said wobble signal thereby generating an improved wobble signal.

9. A wobble processing method as claimed in claim 8 wherein said filtering step uses filtering coefficients chosen so as to minimize the cross-correlation between said improved wobble signal and a data signal generated from said at least two elementary signals.

10. A wobble processing method as claimed in claim 8 wherein said filtering step uses filtering coefficients chosen so as to minimize the difference between a scale version of the improved wobble signal and a reference wobble signal reconstructed based on the generated wobble signal.

11. A program comprising instructions for implementing a wobble processing method as claimed in one of claims 8 to 10, when said program is executed by a processor.

ABSTRACT

METHOD FOR PROCESSING A WOBBLE SIGNAL

A wobble signal is generated from at least two elementary signals detected by scanning a wobbled track of a data carrier.

The invention proposes a solution for eliminating the noise of various origins in the wobble signal, notably the high frequency data leakage into the wobble signal due to radial asymmetry introduced in the diffraction pattern on the detector, whatever the reason for this radial asymmetry.

According to the invention, the at least two elementary signals are filtered with at least an adaptive filter, and said filtered elementary signals are subtracted from said wobble signal thereby generating an improved wobble signal.

Reference: figure 3.

Applications: (re)inscribable optical discs such as DVD+RW, DVD+R, Blu-Ray...

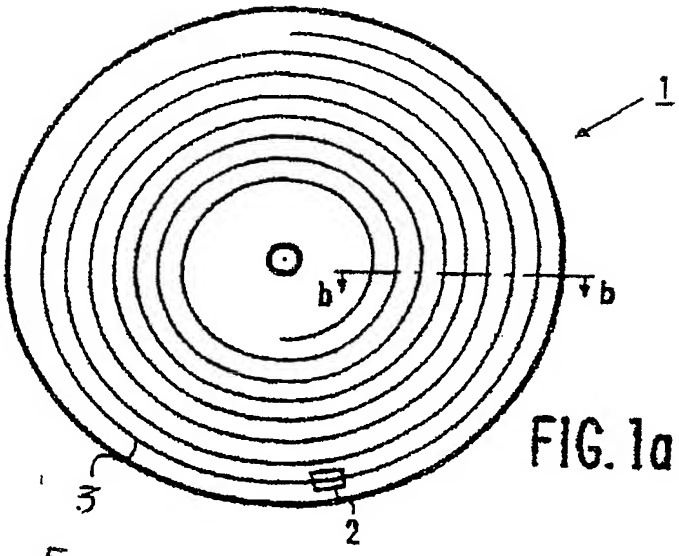

FIG. 1a

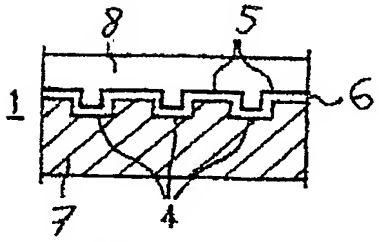

FIG. 1b

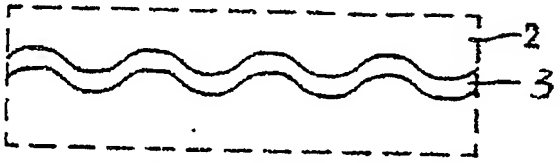

FIG. 1c

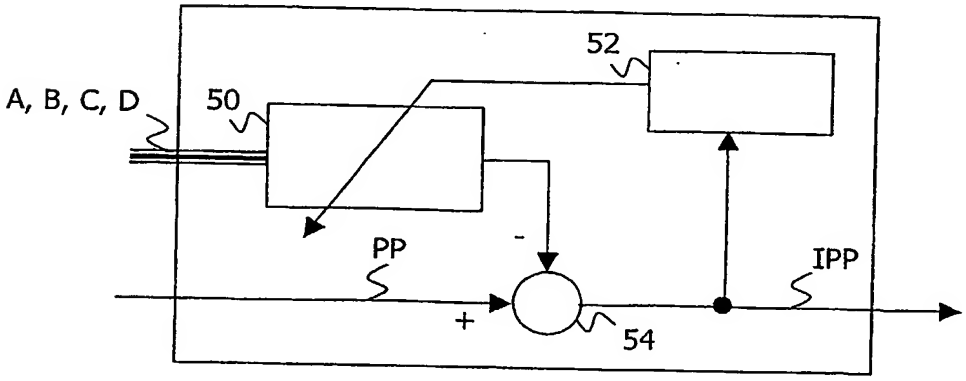

FIG.4

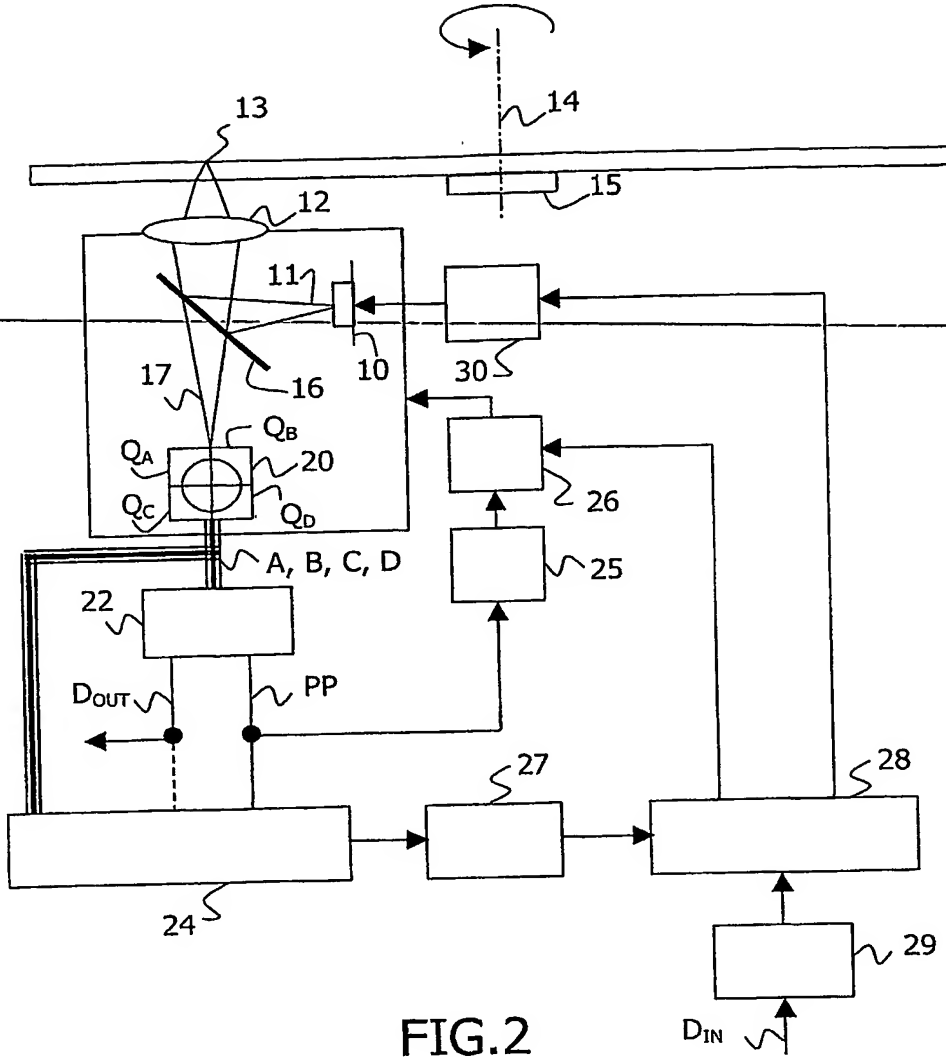
13
14
1
15
12
11
10
30
17
16
Q_B
Q_A
20
Q_C
Q_D
26
25
A, B, C, D
22
D_{OUT}
PP
27
28
24
29
D_{IN}

FIG.2

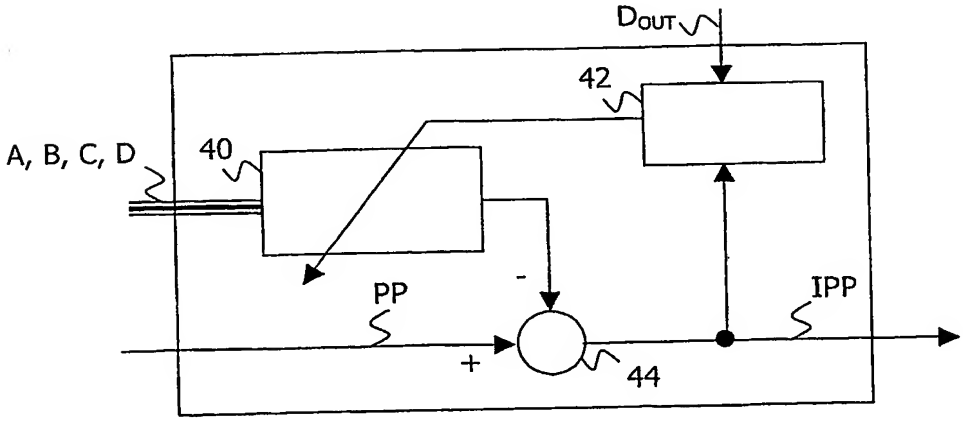
D_{OUT}
42
A, B, C, D
40
PP
-
IPP
+
44

FIG.3

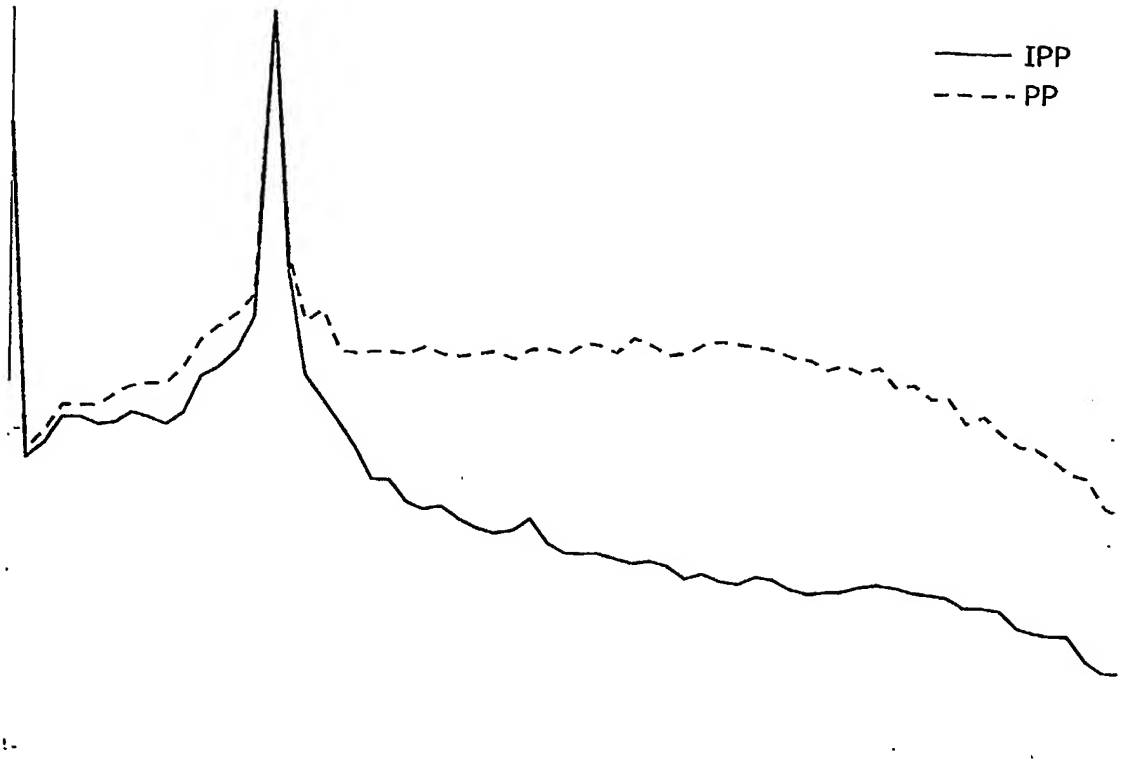

FIG.5

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